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High Index Ring Resonator Coupled to UV-Written Waveguide

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Abstract *High index silicon rich nitride (SRN) ring resonators were coupled to straight UV-written waveguides. Resonance peaks with a free spectral range of 2 nm and a spectral width (fwhm) of 0.2 nm were observed.*

Introduction

Microring resonators have shown promising results for many applications. These include add-drop filters, higher order filters [1], microring lasers and all-optical switches. A viable microring resonator device should have good spectral response, and good coupling with standard optical fiber. It should also be easily manufactured.

Waveguides made with silicon rich nitride (SRN) in glass have a high index contrast (Δn) that permits a smaller bending radius than standard waveguides with germanium doped glass cores. A small bending radius makes the fabrication of high-density integrated circuits, including ring resonators, possible. Standard optical fiber, however, still has a relatively low index contrast. As a result, direct coupling between high-index (SRN) waveguides and standard optical fiber is inefficient and leads to significant signal loss.

We have developed a device fabrication technique that combines high-index (SRN) waveguides and UV-written waveguides [2]. This combination makes a variety of hybrid integrated optical devices possible in which the low-index (UV-written) and high–index (SRN) waveguides are in close proximity. Since UV-writing does not require photolithography or etching, this method avoids many difficulties that may be encountered with multiple lithographic steps. We believe this combination could be developed as a platform for easily interfaced, high-density, integrated optical devices.

In this paper it is shown that UV-written and SRN waveguides can be created on the same substrate and that optical coupling between them can be achieved. The first device made using this technique was a microring resonator. An outline of the fabrication techniques and the performance of the device is given.

Processing of SRN wafer for UV writing

A standard 4-inch silicon wafer with a 12 μm thick thermal oxide layer was used as the substrate for the device. On top of this, a 3.6 μm thick layer of germanium doped silica was deposited using plasma enhanced chemical vapor deposition (PECVD). This is the layer in which low index waveguides were later UV-written. After annealing of the $Ge{:}SiO_2$ layer, a 0.6 μm layer of SRN was deposited using low pressure chemical vapor deposition (LPCVD). After deposition, the SRN layer was annealed to remove possible N-H bonds. Ring structures were defined in the SRN using photolithography and etched using reactive ion etching (RIE). A 12 μm top cladding layer of boron phosphors silica glass (BPSG), index matched to the thermal oxide, was deposited on top of the SRN structures using PECVD. The layer structure is illustrated in figure 1.

The index of the SRN can be varied by adjusting the gas mixture ratio. Based on initial calibration runs the gas mixture was adjusted to yield an index of 2.06 at 1550 nm. The SRN waveguide was 1.4 μm wide and the radius of the SRN ring was 178 μm.

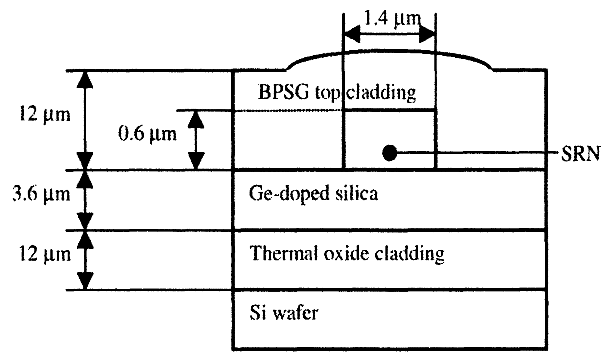

Fig. 1. Structure of the cleanroom processed wafer. The refractive indexes at 1550 nm for the different layers are $Ge{:}SiO_2 = 1.450$, SRN = 2.06 and the thermal oxide = 1.445.

UV-writing of straight waveguides

The wafer containing SRN microrings was diced into 24 mm long chips. Prior to UV writing the sample was loaded with 6 mole% deuterium to enhance the photosensitivity of the Ge-doped core layer. The UV writing setup used of a frequency doubled argon-ion laser that generates a wavelength of 257 nm. The UV beam was focused to a spot size of 3.1 μm on the sample and the incident power was 45 mW. Waveguides were written by scanning the sample underneath the UV beam. The scanning was performed using computer controlled DC translation stages with an absolute precision of 0.1 um. The UV written waveguides were aligned using pre-defined SRN structures as alignment marks. The alignment accuracy was ~0.5 μm.

Two waveguides were written for each microring. One was positioned 100 μm away from the ring so that no coupling would occur and served as a reference. The second was written to nearly intersect the ring structure. After UV writing was completed the sample was annealed at 80 ºC for 24 hours to remove residual deuterium.

Optical microscopy revealed that the width of the UV-written waveguide was 4.6 μm. The index step induced by the UV beam, estimated from measurement of the effective index, was approximately $\Delta n \sim 0.004$. The center-to-center lateral spacing between the high-index waveguide and the UV written waveguide was measured to be 3.4 μm. Hence, the UV written waveguide extended *under* the SRN microring. High-resolution images of the coupling region did not reveal distortions of the UV written waveguide or damage to the SRN material. A microscope overview image of entire structure is shown in figure 2.

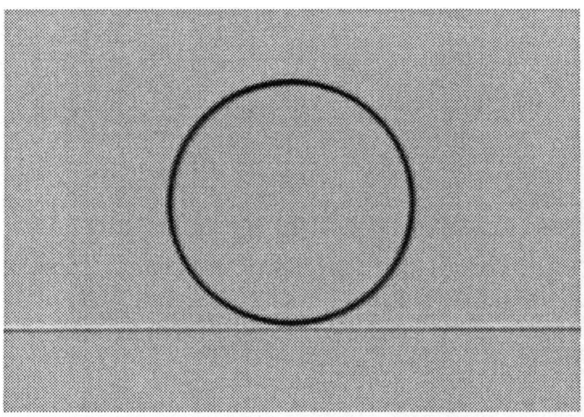

Fig. 2. The SRN microring resonator and UV-written waveguide.

Results

The ring resonator was evaluated by coupling light from a tunable laser into the UV written waveguide. Coupling was performed using index matching oil and standard SMF-28 optical fiber. The total insertion loss (averaged for all polarizations) of reference waveguides was measured to be 3.6 dB, with a polarization dependent loss (PDL) of 0.3 dB. For the waveguides intersecting a SRN ring the insertion loss increased to 5.7 dB, while the PDL increased to 0.5 dB. Further optimization of the scan velocity applied during UV writing has later reduced the insertion loss to 1.3 dB for a reference waveguide. This shows we can obtain insertion losses low enough for practical applications by UV-wirtten waveguides as an interface. When trying to couple directly to SRN waveguides we have previously measured the insertion loss to be 8 dB for a similar waveguide length [3].

The transmission spectra are shown in figure 3. The spectra were recorded for TE and TM polarization separately. The graph show is normalized for clarity. Only the TM polarization showed the dips characteristic of a functioning ring resonator. Lorentzians were fit to these dips and yielded a full width at half maximum (FWHM) of 0.20 +/- 0.02 nm and a free spectral range (FSR) of 2.02 +/- 0.02 nm. These values yield a finesse, F = FSR/FWHM of 10.

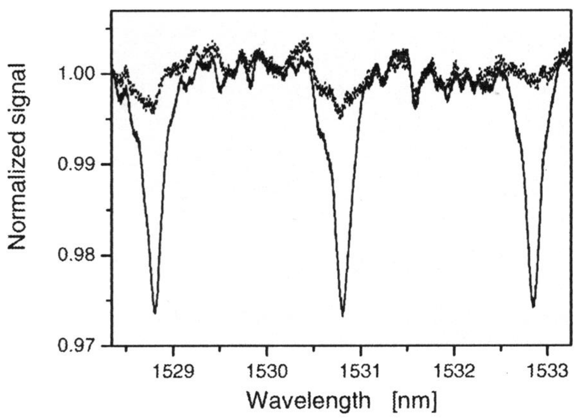

Fig 3. Resonance spectra of a SRN microring resonator with a diameter of 178 um. The dotted spectra is the TE mode and the solid is TM mode.

Conclusion

We have shown that it is possible to combine two waveguide fabrication techniques to produce a hybrid device. Such a hybrid device combines improved coupling to standard fiber and the ability to make high-density integrated optics. Although the performance of the ring resonator needs to be improved to make it a usable device for telecommunications, the results clearly show that there is coupling between the waveguides and that both types of waveguides are functioning well in close proximity. This alone opens up a whole realm of possible devices that can be made with relative ease.

References

1 B.E. Little et al. Journ.l of Lightwave Technology, Vol. 15, No. 6 June 1997
2. M. Svalgaard et al. Elec. Lett. Vol. 30, No 17. 1994
3. K. N. Andersen et al., Accepted for Integrated Photonics Reserch 2002.